The Emulsion Target

The heart of the DONUT experiment is the target box, which may contain up to four emulsion target modules. Emulsion is used as the neutrino interaction target in E872 because of its very high resolution. Such resolution is needed to identify τ decays resulting from ν_τ interaction events.

The emulsion target contains four separate modules aligned and mounted on a precision stand. Each module is made from emulsion sheets, 50 cm × 50 cm in area, oriented perpendicular to the ν beam. A module contains from 50 to 80 individual sheets, depending on the module design, compressed tightly together under vacuum to form a solid unit 6 cm thick. The thickness of the emulsion coating on the sheets varied, depending on the type and location of the module, as discussed below.

In order to minimize the total volume of emulsion to be scanned, the exit points of tracks leaving the modules must be precisely located. To achieve this precision, the target modules are separated by layers of scintillating fibers and special emulsion sheets separate from the modules. These special emulsion sheets are useful only if their track density is much lower than that of the sheets within the module; ideally they should contain of order 1 track per field of view when scanned. The low track density is achieved by replacing the special sheets, known as "changeable sheets", approximately once per week. Thus, the location of tracks within a module follows a chain of increasing precision: Detectors of moderate resolution (drift chambers) are used to find tracks in detectors of higher resolution (scintillating fibers), which, in turn, are used to extrapolate tracks into the changeable sheets. Tracks found in the changeable sheets allow a precise extrapolation into the target module itself.

A diagram depicting the target box configuration is shown in Figure 1. The exterior of the box was covered with a layer of lead, varying from 13 mm to 20 mm in thickness, to protect the emulsion from the ambient radiation during the experimental run.

The type of emulsion used is Fuji EHT 007 / 008 48.

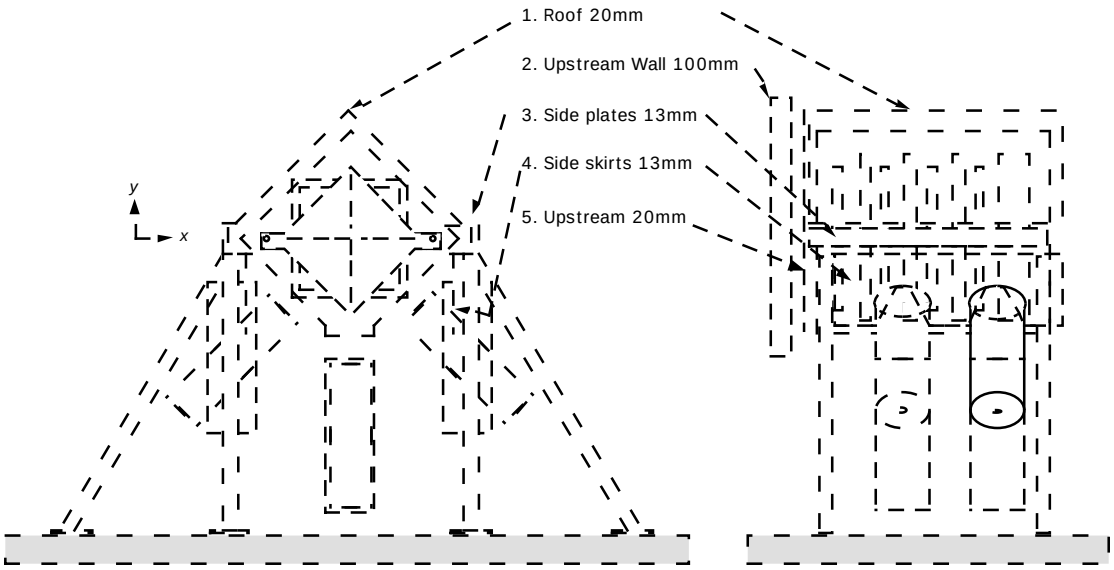

Figure 1. The E872 target box. The diagram depicts the support structure to elevate the target box into the prompt neutrino beam, lead shielding, target modules interspersed with scintillating fiber detectors, and tubes containing the readout electronics for the scintillating fibers.

Bulk Emulsion Modules

The E872 experiment, as originally proposed, used only this type of module. It is the "classic" type of emulsion detector, with 95% of the module mass comprised of nuclear emulsion. Each sheet is made by coating both sides of a 100 μm plastic base with emulsion that dries to a thickness of 360 μm. These sheets, called *bulk*

emulsion, are stacked together, using thin paper sheets as separators, to form a module. A bulk emulsion module contains 84 sheets for a mechanical structure 7 cm thick, of which 6 cm is emulsion. The production process for a bulk module requires 15 liters of emulsion gel.

Emulsion Cloud Chamber Modules

Combination Modules

Changeable Sheets

X-ray sources

To ensure that the proper region of the target is scanned, correct alignment of the changeable sheet with the target emulsion is crucial. This is accomplished with a set of ^{55}Fe radioactive sources, mounted in collimators in the "honeycomb" on the supporting structure for the target and the changeable sheets. Iron-55 decays via electron capture with a half-life of 2.73 years, producing an x-ray of approximately 6 keV. These x-rays make fiducial marks on the changeable sheets and on the target, allowing a precise alignment.

The sources were fabricated from plastic strips coated with ^{55}Fe on one side. The activity of the (new) sources was 120 - 150 kBq/mm^2. Disks 2 mm in diameter were punched from the strips and mounted in brass collimators with a screw which ensured that each source was the same distance from its collimator opening. This provided for uniformity in the fiducial marks. The collimator openings are 1 mm in diameter. Sixteen sources are arrayed on the front and back faces of each target module at intervals of 15 cm.